

Bridging Innovation: A Review of The Emerging Role of Historically Black Colleges and Universities (HBCUs) in Technology Commercialization

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Abstract

Recent studies recognize the pivotal role that Historically Black Colleges and Universities (HBCUs) have played in educating generations of underrepresented engineers and scientists, particularly African Americans. However, their role in advancing research innovation—particularly in the context of commercialization—has been relatively neglected. In recent years, the engineering research and innovation landscape has evolved rapidly, with commercialization becoming a crucial pathway for translating academic discoveries into market products. This is where HBCUs have a unique opportunity to emerge as key players in the innovation ecosystem. Our motivation for this review stems from the growing recognition that HBCUs, despite their historical significance, often face challenges in funding, infrastructure, and access to industry partnerships—factors essential to driving successful research commercialization. Thus, this study aims to explore the emerging role of HBCUs in engineering research innovation, commercialization, and identify key strategies that can enhance their participation in this vital process. The central focus is on exploring how HBCUs can bridge the gap between academic research and market-driven innovation. By analyzing current trends and existing frameworks for commercializing engineering research, we highlight how HBCUs can leverage their institutional strengths, such as strong ties to their communities, diverse student bodies, and commitment to educational access, to contribute meaningfully to the commercialization of engineering research. This work is particularly relevant in the context of broader efforts to diversify the Science, Technology, Engineering, and Mathematics (STEM) workforce and ensure that traditionally underrepresented institutions have equitable access to innovation and commercialization pathways. Moreover, we contribute to the growing discourse on the role of inclusion in the innovation ecosystem by showcasing how HBCUs can serve as pivotal nodes in the commercialization process. We employ a comprehensive literature review of academic and industry sources to examine innovation commercialization in higher education institutions, particularly those serving underrepresented populations. By analyzing research studies, case reports, and industry white papers, we identify key factors contributing to the successful commercialization of engineering research. Our review emphasizes factors such as funding models, university–industry partnerships, intellectual property (IP) management, and student involvement in commercialization activities. Furthermore, we delve into case studies of HBCUs that have successfully commercialized engineering research, providing valuable insights and best practices that can be adapted by other institutions. Our findings indicate that while HBCUs encounter substantial obstacles in their commercialization efforts, they also possess distinctive strengths that can be harnessed to catalyze innovation. In conclusion, by identifying key enablers and barriers, we provide insights into how HBCUs can strategically position themselves as innovative institutions in engineering. These findings have implications for policymakers, educators, and industry leaders who can collaborate to create supportive environments that foster innovation and commercialization at HBCUs. Ultimately, we underscore the critical importance of diversity and inclusion in the innovation process and recommend that empowering HBCUs to

commercialize their research would benefit the entire STEM ecosystem by enabling advancements in science and engineering.

Keywords: Historically Black Colleges and Universities (HBCUs), Technology Commercialization, Innovation Ecosystems, Economic Development, STEM

Introduction

In today's knowledge-driven economy, the ability to translate engineering research into marketable innovations is a critical driver of economic development and societal progress. Universities play an essential role in this process of commercializing innovation by generating new technologies and partnering with industry and government to bring them to market. The "triple helix" model of university–industry–government relations emphasizes the importance of collaboration among these actors in transforming academic research into practical applications and economic value [1], [2], [3]. In addition, research on university–industry engagement highlights that commercialization occurs through a range of formal and informal mechanisms, including collaborative research projects, consulting arrangements, and talent development pipelines, beyond traditional patent licensing alone [4].

Historically Black Colleges and Universities (HBCUs) have educated generations of underrepresented engineers and scientists and have played a critical role in diversifying the STEM workforce in the United States. Although HBCUs represent a small fraction of higher education institutions nationally, they produce a disproportionate share of African American STEM graduates, including many who go on to earn advanced degrees and assume leadership roles in science and engineering fields [5], [6]. This longstanding contribution underscores the importance of HBCUs as engines of human capital development in STEM disciplines.

Despite this significant educational impact, HBCUs remain underrepresented in formal technology transfer and research commercialization activities. Few HBCUs appear among the leading institutions in patent production, licensing revenue, or startup formation, a disparity that is not attributable to a lack of talent or innovative ideas but rather to structural and systemic constraints [7], [8]. These constraints include limited access to research funding, underdeveloped innovation infrastructure, and fewer sustained partnerships with industry—factors that collectively limit HBCUs' capacity to participate fully in commercialization pathways that are increasingly central to engineering research impact.

The underrepresentation of HBCUs in commercialization matters not only from an equity perspective but also from the standpoint of national innovation capacity. Diversity in innovation ecosystems has been shown to enhance creativity, broaden problem-solving approaches, and expand the range of societal challenges addressed through technological advancement. HBCUs, by virtue of their mission, diverse student populations, and strong community ties, are uniquely positioned to contribute to a more inclusive and socially responsive innovation ecosystem [9]. Expanding commercialization opportunities at HBCUs, therefore, represents both an opportunity to advance equity and a strategic imperative for strengthening the overall innovation system.

However, the path toward greater HBCU participation in engineering research commercialization is fraught with challenges. Prior research highlights persistent funding gaps, infrastructure limitations, weaker industry linkages, and low awareness of commercialization processes as barriers that limit innovation outcomes at HBCUs [8], [10], [11], [12]. Faculty at one HBCU engineering school reported that while most had developed innovations with perceived commercial potential, only a minority had successfully commercialized them, citing “missing” or “lacking” commercialization resources and limited industry engagement [10]. Parallel survey work at another HBCU found low levels of awareness among both graduate and undergraduate engineering students regarding commercialization pathways, innovation programs, and initiatives such as NSF I-Corps [11], [12]. National data further indicate that minority-serving institutions, including HBCUs, receive a smaller share of federal research and development funding compared to predominantly White research-intensive universities, limiting their ability to invest in laboratories, technology transfer offices, and entrepreneurial programming [13]. These structural challenges can create a cycle in which limited capacity restricts competitiveness for funding, further reinforcing disparities in commercialization outcomes.

At the same time, HBCUs possess distinctive strengths that can be leveraged to overcome these barriers. Supportive learning environments, strong mentorship networks, and a demonstrated commitment to student success have contributed to higher persistence rates among underrepresented students in STEM fields [14]. These same institutional characteristics can be extended into innovation and entrepreneurship training, creating pathways for students and faculty to translate research into real-world applications. Moreover, HBCUs often function as anchor institutions within their local communities, positioning them to advance community-based innovation and inclusive economic development through commercialization activities [9].

The purpose of our paper is to explore the emerging role of HBCUs in engineering research innovation commercialization and to identify key strategies that can enhance their participation in this process. Specifically, our study examines how HBCUs can bridge the gap between academic research and market-driven innovation by leveraging funding mechanisms, strengthening university–industry partnerships, improving intellectual property management practices, and expanding student involvement in entrepreneurship and commercialization activities.

Our work contributes to the growing body of literature on innovation ecosystems and STEM diversity by centering HBCUs as critical yet often overlooked actors in engineering research commercialization. By synthesizing existing research and highlighting illustrative case studies, our paper provides insights relevant to policymakers, higher education leaders, and industry partners seeking to build more inclusive and effective innovation systems.

We organized our paper as follows: we begin with the introduction, followed by a review of the literature on the historical role of HBCUs in STEM education, the innovation commercialization ecosystem in higher education, and the importance of diversity and inclusion in innovation. This is followed by a description of the methodology, a presentation of the findings, a discussion of the implications, and concluding recommendations.

Literature review

Historical role of HBCUs in STEM education

Historically Black Colleges and Universities (HBCUs) have a long and storied history in producing African American scientists, engineers, and innovators. Founded primarily in the post-Civil War era to educate Black Americans who were barred from many predominantly White institutions, HBCUs became foundational in nurturing talent that would otherwise have been excluded from higher education [15]. Over the decades, HBCUs have consistently demonstrated a huge impact in STEM education, especially for minority students. Although they represent a small proportion of higher education institutions nationally, HBCUs award a significant share of bachelor's degrees in science and engineering to black students and have been particularly successful in motivating students to pursue advanced degrees [5], [6].

The supportive academic climate of HBCUs has been cited as a key factor in their success at broadening participation in STEM. Research suggests that students at HBCUs experience a stronger sense of belonging, mentoring, and affirmation, which can counteract stereotype threat and feelings of isolation often reported by underrepresented students at predominantly White institutions [14]. These supportive environments contribute to higher retention and persistence rates in STEM disciplines and expand the national pipeline of minority engineers and scientists [16]. As a result, HBCUs have produced graduates who have made substantial contributions in academia, industry, and government research laboratories.

Despite this strong educational legacy, the role of HBCUs in engineering research commercialization has historically been limited. While many HBCUs have increased their research activity over the past two decades, they have not been as deeply embedded in formal technology transfer systems as large research-intensive universities. The passage of the Bayh-Dole Act catalyzed the expansion of university patenting and licensing activity nationwide, but HBCUs were slower to develop the infrastructure and administrative capacity required to participate fully in these commercialization pathways [1], [16]. This lag reflects not a lack of innovative potential, but rather long-standing disparities in research funding, infrastructure investment, and institutional scale.

The innovation commercialization ecosystem in higher education

The broader literature on innovation commercialization in higher education emphasizes the importance of the university-industry-government nexus. The “triple helix” model conceptualizes innovation as a dynamic interaction among universities that generate knowledge, industries that translate discoveries into products, and governments that provide funding and policy support [1]. Within this framework, universities increasingly function as economic actors, engaging in patenting, licensing, startup formation, and industry-sponsored research. Perkmann and colleagues emphasize that commercialization extends beyond patents to include collaborative research, consulting, and informal knowledge exchange, all of which can serve as pathways for translating academic research into societal impact [4], [17].

However, access to these commercialization mechanisms is unevenly distributed across institutions. Research on academic capitalism highlights that well-resourced universities are better positioned to engage in market-oriented research, while institutions with limited resources

may struggle to invest in technology transfer offices, legal expertise, and entrepreneurial programming [16]. This resource dependency is particularly salient for HBCUs, which have historically received lower levels of federal and private research funding relative to predominantly White research-intensive universities [7], [18].

Funding disparities represent one of the most significant barriers to innovation commercialization at HBCUs. Federal research and development data consistently show that minority-serving institutions, including HBCUs, receive a smaller share of federal R&D obligations than their non-HBCU counterparts [16], [13]. Limited access to sustained research funding constrains the ability of HBCUs to invest in laboratory infrastructure, hire commercialization staff, and support early-stage proof-of-concept development. In addition, venture capital and private investment have historically been less accessible to HBCU-affiliated startups, further limiting commercialization opportunities [7].

Infrastructure limitations compound these funding challenges. Effective commercialization requires not only strong research output but also institutional support structures such as technology transfer offices, incubators, prototyping facilities, and clear intellectual property policies [19]. Many HBCUs either lack dedicated technology transfer offices or operate with minimal staffing and resources, making it difficult to identify, protect, and market intellectual property [9]. Even when promising inventions emerge, limited access to patenting funds and commercialization expertise can prevent these technologies from advancing beyond the laboratory stage.

Industry partnerships are another critical component of successful commercialization that has historically been underdeveloped at many HBCUs. Sustained collaborations with industry provide access to applied research problems, market insights, and pathways for scaling innovations [20]. However, HBCUs often have fewer formal relationships with large corporations and fewer alumni networks embedded in major technology firms, limiting opportunities for sponsored research and co-development [4], [7]. While recent years have seen growing interest from industry partners seeking to diversify their talent pipelines and research portfolios, these partnerships remain unevenly distributed across institutions.

Other key barriers noted in the literature include cultural and informational gaps (faculty at teaching-focused HBCUs may be less aware of commercialization processes or incentive structures may not reward it), and student exposure (fewer programs to expose students to entrepreneurship) [10], [12].

Table 1 summarizes the primary barriers to innovation commercialization at HBCUs identified in the literature.

Table 1: Key barriers to innovation commercialization at HBCU

Barriers	Description	Example
Funding gaps	Limited access to federal research funding, venture capital, and commercialization grants	Underrepresentation of HBCUs in NSF and NIH funding portfolios [18]

Barriers	Description	Example
Infrastructure Deficiencies	Insufficient laboratory facilities, incubators, and technology transfer offices	Outdated research equipment, and small or non-existent technology transfer staff [7]
Industry partnerships	Few sustained collaborations with major corporations	Few sustained collaborations with major corporations [4]
Cultural and Informational gaps	Low level of awareness of commercialization processes, and academic culture focused more on teaching than startups or patents	Faculty not incentivized to patent or form companies; students lack entrepreneurship training opportunities and role models in technology entrepreneurship [10], [11], [12]

While these barriers are substantial, the literature also highlights the importance of diversity and inclusion in innovation ecosystems as a compelling rationale for expanding commercialization capacity at HBCUs. Diverse innovation ecosystems are associated with greater creativity, broader problem-solving approaches, and more socially responsive technological solutions [9]. HBCUs, by virtue of their mission and demographics, are uniquely positioned to contribute to inclusive innovation by ensuring that underrepresented communities are not only beneficiaries of innovation but also active participants in the innovation process.

Community-based innovation represents a particularly important dimension of HBCU engagement in commercialization. Many HBCUs serve as anchor institutions within economically disadvantaged communities and have long-standing relationships with local governments, schools, and businesses. It has been argued that HBCUs can leverage these relationships to create innovation ecosystems that address local and regional challenges while generating broader economic impact [8], [9]. Commercialization activities that emerge from such contexts may prioritize applications in areas such as health equity, environmental justice, education technology, and infrastructure resilience, thereby aligning innovation outcomes with social needs.

Recent policy discussions further underscore the strategic importance of strengthening HBCUs' innovation capacity. Federal agencies and national organizations have increasingly emphasized the need to support research and commercialization at minority-serving institutions as part of broader efforts to enhance equity in STEM and innovation [13],[21]. Reports from the U.S. Department of Education and the National Science Foundation call for targeted investments in research infrastructure, expanded access to commercialization training programs, and stronger integration of HBCUs into national innovation networks [21].

In summary, the literature suggests that while HBCUs have historically been marginalized within formal commercialization ecosystems, they possess significant untapped potential to contribute to engineering research innovation. Addressing persistent barriers to funding, infrastructure, industry engagement, and cultural and information gaps—while leveraging institutional strengths

in diversity, community engagement, and student support—can enable HBCUs to play a more prominent role in bridging academic research and market-driven innovation.

Methodology

Our study employs a comprehensive literature review as our primary methodological approach. We selected a literature review because the objective of this work is to synthesize existing knowledge on the role of Historically Black Colleges and Universities (HBCUs) in engineering research, innovation, and commercialization, rather than to collect primary empirical data. Our approach enables a broad examination of trends, challenges, and best practices across higher education institutions and innovation ecosystems, with particular attention to institutions serving underrepresented populations.

Our review process followed a structured, multi-stage approach consisting of five primary steps: (1) database and source identification, (2) screening and selection of relevant literature, (3) thematic analysis, (4) identification and examination of illustrative case studies, and (5) synthesis and reporting (See Figure 1 below). Our framework ensured systematic coverage of both academic scholarship and practitioner-oriented sources relevant to research commercialization and HBCUs.



Figure 1: Summary of Our Approach

Our initial database search included major academic and interdisciplinary databases, including Google Scholar, Web of Science, IEEE Xplore, ERIC, and Scopus. Search terms included combinations of keywords such as “HBCU technology commercialization,” “innovation ecosystems in higher education,” “minority-serving institutions and research commercialization,” “university–industry partnerships,” and “engineering entrepreneurship.” In addition to peer-reviewed journal articles, our search included government reports, policy briefs, industry white papers, and institutional publications to capture recent developments and applied perspectives that may not be well represented in academic journals.

After our initial searches yielded approximately 50 sources, we screened sources for relevance and quality. Inclusion criteria required that sources directly address one or more of the following

areas: innovation commercialization in higher education, technology transfer mechanisms, research commercialization barriers or enablers, university–industry collaboration, or the role of minority-serving institutions in STEM innovation. This left us with 27 core sources. In doing this, we gave preference to peer-reviewed publications and official reports from federal agencies or reputable organizations. We included foundational theoretical works on innovation systems and university commercialization to provide conceptual grounding, even if they did not focus specifically on HBCUs [1], [4], [16].

Once we had identified relevant sources, we conducted full-text reviews to extract key concepts, findings, and examples. We used a thematic analysis approach to organize the literature into recurring categories aligned with the objectives of our study. These themes included funding models for commercialization, institutional infrastructure and capacity, university–industry partnerships, intellectual property management practices, and student engagement in innovation and entrepreneurship. Our thematic structure guided the organization of findings and facilitated comparison across institutions and studies.

In addition to the thematic analysis, we selected case studies of HBCUs to provide concrete illustrations of commercialization pathways in practice. Our case study selection was based on documented evidence of commercialization activity, such as the presence of formal technology transfer offices, participation in federal innovation programs, industry-sponsored research partnerships, patenting activity, or structured entrepreneurship initiatives. Institutions highlighted in the case studies include Howard University, Morgan State University, North Carolina A&T State University, and Florida A&M University, among others. Our selected cases were not intended to be exhaustive or comparative in a statistical sense, but rather illustrative of different approaches and stages of commercialization development within the HBCU landscape.

We synthesized the data we extracted from the literature qualitatively to identify patterns, common challenges, and promising strategies. Our emphasis was placed on identifying both barriers that constrain commercialization at HBCUs and enablers that have contributed to successful outcomes. Where possible, our findings from multiple sources were triangulated to enhance reliability and reduce reliance on single-institution narratives.

While our methodology provides a comprehensive overview of the existing literature, it is not without limitations. As a review-based study, our findings are dependent on the scope and quality of available sources and do not include original empirical data collection. Additionally, the rapidly evolving nature of innovation ecosystems means that some institutional initiatives may not yet be fully documented in the academic literature. Nevertheless, our approach is appropriate for establishing a synthesized understanding of the current state of HBCU engagement in engineering research commercialization and for identifying areas warranting further empirical research.

Findings/Results

Our findings from the comprehensive literature review reveal several interrelated themes that shape the ability of Historically Black Colleges and Universities (HBCUs) to participate effectively in engineering research innovation commercialization. These themes include (1)

funding models that support commercialization, (2) the role of university–industry partnerships, (3) intellectual property (IP) management practices, and (4) student engagement in entrepreneurship and commercialization activities. Together, these findings illustrate both the structural challenges HBCUs face and the mechanisms through which successful commercialization has occurred.

Funding models supporting commercialization

One of the most prominent findings relates to the importance of diversified funding models in supporting commercialization activities at HBCUs. The literature consistently emphasizes that commercialization is resource-intensive and requires sustained investment beyond traditional research funding. Federal and state programs play a critical role in this regard by providing funding for early-stage technology development, proof-of-concept activities, and market assessment. Programs such as the National Science Foundation’s Innovation Corps (I-Corps) initiative have been identified as particularly valuable for academic institutions seeking to translate research into market-ready technologies [21]. Participation in such programs enables faculty and students to gain exposure to customer discovery processes, entrepreneurial training, and mentorship, thereby strengthening the commercialization pipeline.

In addition to federal programs, state-level funding and philanthropic investments have been shown to support innovation infrastructure and commercialization capacity at select HBCUs. These investments often target the development of research facilities, innovation centers, and entrepreneurship programs that serve as platforms for translating engineering research into applied solutions. The literature suggests that when HBCUs are able to access a mix of federal, state, and private funding sources, they are better positioned to sustain commercialization efforts and reduce reliance on a single funding stream [7], [8].

The role of university–industry partnerships

University–industry partnerships emerge as another critical enabler of successful commercialization. Our review highlights that partnerships with industry provide access to applied research problems, technical expertise, market insights, and downstream commercialization opportunities. Such partnerships can take the form of sponsored research agreements, joint development projects, or long-term collaborative relationships. Evidence from the literature indicates that HBCUs with established industry partnerships are more likely to advance engineering research beyond the laboratory and into practical applications [4].

Case studies further illustrate the value of these partnerships. For example, Florida A&M University’s collaboration with Lockheed Martin in support of NASA-related research demonstrates how industry engagement can provide both financial resources and experiential learning opportunities for students while advancing applied engineering research [22]. Similarly, other HBCUs have leveraged partnerships with defense, energy, and technology firms to align faculty expertise with industry needs, thereby enhancing the commercial relevance of their research portfolios.

Intellectual property (IP) management practices

Effective management of intellectual property is another key factor influencing commercialization outcomes at HBCUs. The literature indicates that institutions with dedicated

technology transfer offices or clearly defined IP management processes are more likely to identify, protect, and commercialize research outputs. IP management practices include invention disclosure procedures, patent filing support, licensing strategies, and startup facilitation. While many HBCUs have historically lacked robust IP infrastructure, recent efforts to strengthen technology transfer capacity have yielded measurable results at select institutions [8].

Howard University provides a notable example of structured IP management through its Office of Research and Technology Transfer, which actively supports faculty and student innovators in protecting and commercializing intellectual assets [16]. Similarly, North Carolina A&T State University has reported successful licensing of engineering research innovations, demonstrating that focused investment in IP management can lead to tangible commercialization outcomes [23]. These examples suggest that even modest investments in technology transfer capacity can significantly improve commercialization performance.

Student engagement in entrepreneurship and commercialization activities

Student engagement in entrepreneurship and commercialization activities represents a fourth major theme identified in the findings. The literature underscores the importance of involving students in innovation ecosystems as both contributors to research commercialization and future leaders of technology-driven enterprises. HBCUs that offer innovation hubs, incubators, pitch competitions, and entrepreneurship training programs provide students with experiential learning opportunities that complement traditional engineering education [9], [24].

Student involvement not only enhances the commercialization potential of research projects but also contributes to workforce development by equipping graduates with entrepreneurial skills and an understanding of market dynamics. Evidence suggests that such programs can increase students' interest in pursuing careers in innovation, startups, or industry research, thereby extending the impact of commercialization initiatives beyond individual projects [24]. Furthermore, student-led ventures emerging from HBCU innovation programs often reflect community-oriented perspectives, aligning technological solutions with social and economic needs.

Table 2 summarizes the key enablers of successful commercialization at HBCUs identified in the literature, the mechanisms through which they operate, and illustrative examples of their implementation.

Table 2. Enablers of successful commercialization at HBCUs

Enabler	Mechanism	Example of implementation
Federal and private funding	Provides resources for prototyping, market assessment, and early-stage scaling of engineering research	Participation in NSF I-Corps and related federal innovation programs [21]. Howard University and others have sent teams to I-Corps, gaining funding and mentorship to explore commercializing their engineering research.

Enabler	Mechanism	Example of implementation
University–industry partnerships	Facilitates access to applied research problems, industry expertise, and commercialization pathways. Done through networking, establishing centers of excellence and creating of consortia	Lockheed Martin–FAMU collaboration: A \$5M, five-year research partnership engages FAMU faculty/students in NASA vehicle R&D, providing funding and pathways for student employment [22]
Intellectual property management	Enables protection and licensing of innovations through structured technology transfer processes – clear IP policies, incentives for faculty/innovators, skilled staff or consultants, marketing and partnerships	Technology transfer operations at Howard University [24]; licensing activity at North Carolina A&T State University [23]
Student involvement	Builds entrepreneurial capacity and sustains innovation pipelines through experiential learning -	Innovation hubs, competitions (Pitch competitions: Howard’s PitchHU has funded 12+ student/alumni startups in 3 years), and entrepreneurship programs at HBCUs [24]

In addition to tabular summaries, the literature suggests notable disparities in commercialization outcomes between HBCUs and non-HBCU research-intensive institutions. While comprehensive comparative data are limited, existing studies and reports indicate that HBCUs generally report lower levels of patenting, licensing revenue, and startup formation relative to predominantly White research universities with similar disciplinary profiles [7], [18]. This disparity underscores the cumulative effects of funding, infrastructure, and partnership gaps discussed throughout the findings.

Overall, the findings indicate that while HBCUs face persistent structural barriers in engineering research commercialization, they also demonstrate significant potential to advance innovation through strategic investments in funding diversification, industry partnerships, IP management, and student engagement. These results provide a foundation for the discussion of implications and recommendations presented in the following section.

Discussion

Our findings, presented in the previous section, reveal a complex yet increasingly promising landscape for engineering research innovation commercialization at Historically Black Colleges and Universities (HBCUs). Taken together, the barriers and enablers identified in the literature highlight both the structural constraints that have historically limited HBCU participation in commercialization and the strategic opportunities that can enable these institutions to play a more prominent role in innovation ecosystems.

Funding, infrastructure, and institutional capacity

A central theme emerging from our findings is the interconnected nature of funding, infrastructure, and institutional capacity. Limited access to sustained research and commercialization funding constrains HBCUs' ability to invest in laboratories, technology transfer offices, and entrepreneurial programming, which in turn affects their competitiveness for additional funding and partnerships [7], [8], [18]. This cyclical relationship reinforces disparities in commercialization outcomes between HBCUs and well-resourced research-intensive universities. Without targeted interventions, HBCUs may remain caught in a cycle where insufficient capacity limits output, and limited output reduces access to future investment.

Strategic investments

At the same time, our findings suggest that strategic investments—even when modest in scale—can have a disproportionate impact on commercialization outcomes. Federal programs such as NSF I-Corps and similar initiatives provide not only financial resources but also critical exposure to customer discovery, market validation, and entrepreneurial skill development [18], [21]. Participation in these programs can serve as a catalyst for cultural change within institutions by normalizing commercialization as a legitimate extension of academic research. As faculty and students gain familiarity with commercialization processes, the likelihood of invention disclosures, patent filings, and startup formation increases.

Sustained university-industry partnerships

University–industry partnerships emerge as another powerful lever for expanding commercialization capacity at HBCUs. The literature and case studies demonstrate that sustained industry collaborations provide access to applied research problems, technical expertise, and commercialization pathways that are often unavailable within academic settings alone [4], [25]. Partnerships such as the Florida A&M University–Lockheed Martin collaboration illustrate how aligning institutional research strengths with industry needs can generate mutual benefits, including funding, workforce development, and applied research outcomes [22]. These examples suggest that HBCUs can enhance commercialization success by strategically cultivating long-term industry relationships rather than relying on isolated or short-term engagements.

Effective intellectual property management

Effective intellectual property management further differentiates institutions that have achieved measurable commercialization outcomes from those that have not. The presence of dedicated technology transfer offices, clear IP policies, and institutional support for patenting and licensing is consistently associated with higher levels of commercialization activity [8]. Case examples from Howard University and North Carolina A&T State University demonstrate that structured IP management processes can enable HBCUs to translate engineering research into licensed technologies and startups [24], [23]. Importantly, these cases indicate that HBCUs do not need to replicate the scale of large research universities to be successful; rather, focused investments in IP support and faculty engagement can yield meaningful results.

Increased student engagement in entrepreneurship

Student engagement in entrepreneurship and innovation represents a particularly important dimension of commercialization at HBCUs. Our findings highlight that innovation hubs, incubators, and entrepreneurship programs offer experiential learning opportunities that

complement traditional engineering education and prepare students to pursue commercialization pathways [9], [21]. These programs not only support the development of student-led ventures but also contribute to workforce readiness by equipping graduates with skills valued in industry and startup environments. Moreover, student-driven innovation at HBCUs often reflects community-oriented perspectives, aligning commercialization activities with broader social and economic goals.

The role of diversity and inclusion in innovation ecosystems

The role of diversity and inclusion in innovation ecosystems is a critical lens through which these findings should be interpreted. Expanding commercialization at HBCUs has implications beyond institutional performance metrics; it directly contributes to diversifying who participates in innovation and which problems are prioritized for technological solutions [9]. HBCUs' strong ties to underrepresented communities position them to advance community-based innovation that addresses societal challenges such as health disparities, environmental justice, and educational access. In this sense, commercialization at HBCUs can serve as a mechanism for inclusive economic development rather than solely a revenue-generating activity.

Policy perspective

From a policy perspective, our findings underscore the importance of coordinated efforts among federal agencies, higher education leaders, and industry partners. Federal investments targeted at minority-serving institutions can help address structural inequities in research funding and commercialization capacity [18], [26], [27]. At the institutional level, HBCU leadership plays a critical role in setting priorities, allocating resources, and signaling the value of innovation and entrepreneurship within academic cultures. Industry partners, in turn, have an opportunity to engage HBCUs as collaborators in research and development while simultaneously strengthening diverse talent pipelines.

Overall, the discussion suggests that while challenges remain, HBCUs are well-positioned to expand their role in engineering research, innovation, and commercialization through intentional strategies that leverage funding opportunities, partnerships, IP management, and student engagement. The convergence of growing policy attention, industry interest, and institutional commitment presents a timely opportunity to reposition HBCUs as integral contributors to inclusive and impactful innovation ecosystems.

Conclusion and recommendations

Our paper set out to explore the emerging role of Historically Black Colleges and Universities (HBCUs) in engineering research innovation commercialization and to identify strategies that can enhance their participation in this critical aspect of the modern innovation ecosystem. Through a comprehensive review of academic literature, policy reports, and illustrative case studies, the study examined the structural barriers that have historically constrained commercialization at HBCUs as well as the enabling mechanisms that have supported successful outcomes at select institutions.

The findings demonstrate that while HBCUs continue to face substantial challenges related to funding disparities, infrastructure limitations, and access to industry partnerships, these barriers

are not insurmountable. Rather, they reflect systemic conditions that can be addressed through intentional investment, policy alignment, and institutional commitment. Importantly, the review highlights that HBCUs possess distinctive strengths—including strong community engagement, diverse and resilient student populations, and supportive academic environments—that position them to contribute meaningfully to inclusive innovation and economic development.

A central conclusion of our study is that commercialization at HBCUs should not be viewed solely through the lens of revenue generation or technology transfer metrics. Instead, it should be understood as a strategic extension of the HBCU mission to expand access, promote equity, and generate societal impact through engineering research. We posit that, when effectively supported, commercialization activities at HBCUs can diversify the innovation workforce, broaden the scope of problems addressed through engineering solutions, and strengthen regional and national innovation ecosystems.

Based on the synthesis of findings, we propose several strategic recommendations to strengthen engineering research commercialization at HBCUs.

First, HBCUs should work to strengthen and diversify funding pipelines that support commercialization activities. This includes increasing participation in federal innovation and commercialization programs, such as early-stage technology development and customer discovery initiatives, as well as pursuing state and philanthropic investments to build long-term innovation capacity. Developing internal seed funding mechanisms, even at modest levels, can also help bridge the gap between research and market readiness.

Second, sustained investment in research and innovation infrastructure is essential. HBCUs should prioritize developing or expanding technology transfer offices, intellectual property management systems, and innovation spaces, such as incubators and prototyping laboratories. Where resources are limited, collaborative or shared-service models across institutions may offer a viable pathway for building capacity while reducing costs.

Third, building robust and enduring university–industry partnerships should be a strategic priority. HBCUs can enhance commercialization outcomes by aligning their research strengths with industry needs, formalizing partnerships through sponsored research agreements, and leveraging alumni networks to facilitate industry engagement. Long-term, trust-based partnerships are particularly valuable for advancing applied research and creating pathways for scaling innovations.

Fourth, expanding student-focused innovation and entrepreneurship training is critical for sustaining commercialization ecosystems at HBCUs. Integrating entrepreneurship education into engineering curricula, supporting experiential learning through innovation hubs and competitions, and providing mentorship opportunities can prepare students to serve as drivers of commercialization efforts. These initiatives also contribute to workforce development by equipping graduates with skills relevant to both industry and startup environments.

Finally, our study underscores the importance of continued research and policy attention to HBCUs' role in innovation ecosystems. Future research should examine longitudinal outcomes

of commercialization initiatives at HBCUs, assess the effectiveness of specific funding and partnership models, and explore the broader economic and social impacts of HBCU-led innovation. Policymakers and funding agencies should continue to develop targeted programs that recognize the unique contexts and contributions of HBCUs while promoting equitable access to commercialization pathways.

In conclusion, HBCUs occupy a critical yet underrecognized position in the landscape of engineering research commercialization. By addressing structural barriers and leveraging institutional strengths, HBCUs can bridge the gap between academic research and market-driven innovation in ways that advance both technological progress and social equity. Strengthening commercialization at HBCUs is therefore not only an institutional imperative but also a national opportunity to build a more inclusive and impactful innovation ecosystem.

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